Lumby — Lavington Air Quality 1975–1990

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LUMBY-LAVINGTON AIR QUALITY

1975 - 1990

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EXECUTIVE SUMMARY

This report was compiled because an earlier report on air quality in the whole Okanagan Sub-Region indicated that Lumby had particularly poor air quality. This report presents air monitoring data of waste management permit holders as well as B.C. Environment. The data are analyzed in various statistical and graphical ways to describe the nature and trends in air quality near Lumby and Lavington during the period 1975-1990.

In this report, air quality is measured with two parameters. One method is the total amount of particulate matter which is suspended in the air over a 24 hour period. This is called Total Suspended Particulate (TSP). The other measure of air quality is dustfall, the amount of material which falls out of the air during the sampling period. The period is two weeks, in the case of permittee dustfall samplers and one month in the case of B.C. Environment dustfall samplers. Both the dustfall which consists of wood material (combustible dustfall) and dustfall which is not burnable (non-combustible dustfall) are described in this report. The two kinds of dustfall summed together are total dustfall.

TSP (total suspended particulate) in the Lumby area was higher than most other locations in British Columbia where TSP was measured. TSP often exceeded the guidelines for good air quality. Dustfall in Lumby was also high relative to other parts of British Columbia and it also often exceeded the accepted standards for good air quality.

Air quality was poor mainly because up to seven lumber mills were emitting wastes from their woodwaste burners in a fairly narrow valley. Air quality improved whenever one of the mills shut down, either temporarily or permanently. Air quality in Lumby improved between the 1970's and 1980's when all mills improved the nature and operation of their burners. Likewise there was less woodwaste in the dustfall when Lavington Planer Mill installed an olivine burner instead of its teepee burner. Permanent closure of the Fletcher Challenge mill in 1989 also improved air quality in Lumby.

The information in this report will be useful in bringing about changes to improve air quality in the Lumby and Lavington valleys.

TECHNICAL ABSTRACT

This report summarizes the available data on dustfall and suspended particulate levels from 1975 to 1990 for the Lumby - Lavington area. Both total suspended particulate and dustfall levels were high relative to both other sites in the province and to provincial air quality objectives. The mean total suspended particulate level for 1983 - 1990 was 70 ug/m^3, compared to the provincial A level of 60 ug/m^3. From 1975 to 1990, at 6 of the 7 dustfall samplers in the Lumby - Lavington area, over 80% of the total dustfall measures exceeded the provincial A level of 1.75 mg/dm^2/day.

There was no demonstrable relationship between dustfall and mean monthly precipitation. Combustible dustfall was highest in those months with the lowest mean temperature. There was a strong positive correlation between combustible dustfall measured at each of the Lumby samplers (i.e. when dustfall was relatively high at one sampler it was generally high at the other samplers). There was no simple, demonstrable relationship between wind conditions and dustfall.

Levels of combustible dustfall and total suspended particulates in the Lumby area are related, but there was no similar relationship between combustible dustfall in Lumby and suspended particulates in Vernon. Dustfall decreased with distance from a burner. Dustfall in Lavington did not appear to be linked to dustfall in Lumby. There was little similarity between dustfall levels in B.C.E. samplers and permittee samplers located nearby.

At Lumby Centre, the same proportion of combustible dustfall measures exceeded the Provincial A and B levels after 1983 as before. There was, however, a decrease in the proportion of total dustfall and suspended particulate measures exceeding Federal and Provincial levels since 1983. Combustible dustfall in Lumby Centre dropped when the Fletcher Challenge mill was closed by an industrial dispute, and when its burner was destroyed by a fire. Dustfall at the Ruesch residence was also related to productivity at the Fletcher Challenge mill. There has also been a decrease in dustfall since the mill closed permanently in 1989 (combustible dustfall down from 1.47 to 0.58 mg/dm^2, and suspended particulates down from 71 to 60 ug/m^3). However, similar drops in dustfall were also observed at samplers around other mills in the Lumby area and in Lavington. Dustfall and TSP decreased at Lumby Home Furnishings when Fletcher Challenge closed permanently in 1989.

Air samples taken around the Weyerhaeuser mill showed no decrease in the mean dustfall, or the proportion of measures exceeding suggested governmental levels 1983-89. From 1984 - 1989 over 50% of dustfall measures exceeded 1.75 mg/dm^2/d, however this has dropped to 10% since the beginning of 1989.

There were several trends at other mills in Lumby. Bell Pole permittee and B.C.E. samplers at Duteau Creek have yearly mean combustible dustfall 2-4 times greater than the permitted objective discharge level of 1.75 mg/dm^2/day. Daily differences in dustfall at four sites around the Bell Pole burner could not be related to variations in wind speed and direction measured at the same site. There has been an increase in combustible dustfall west of the Riverside mill since 1983; however this may be an artifact of the samplers having been relocated during that time. Burner temperatures show the Gorman Brothers burner consistently operates below optimum temperature.

Combustible dustfall has decreased at Lavington since installation of the refractory burner in October 1985. There were dramatic increases in non-combustible dustfall in the years following 1985, but the peaks in non-combustible dustfall at the Lavington East and Lavington Harber sites were not in the same year, suggesting some source other than the burner.

PREFACE

The goal of the Air Management Program of British Columbia is to maintain or improve air quality in British Columbia. This report describes air quality in the Lumby-Lavington area. It shows examples where air quality has improved as a result of actions taken by B.C. Environment and the lumber mills. It also shows that air quality is still below measures of acceptability. This report will serve as a useful benchmark in establishing that the Air Management Program can achieve its goal in the Lumby-Lavington airshed.

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A number of B.C. Environment staff reviewed and offered comment on this report: P. Jarman, P. Reid, B. Manna, R. Davis and D. Hall. A summary of the report was presented verbally to his Worship Mayor Simpson of Lumby and interested members of Lumby council and staff in July 1990. Their ideas and comments were useful. Assistance in typing was given by Bev Russell and Jeanette Myers.

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1. INTRODUCTION

This report is a collation of data pertinent to air quality in the Lumby-Lavington airshed. The main focus of the report is the probable effect on air quality of the numerous woodwaste burners located in the valley. Seven woodwaste burners, local topography, the high frequency of temperature inversions, and a dry climate combined to make the quality of air in the Lumby - Lavington area among the worst in British Columbia. (Richardson, Jensen and Bryan 1991).

The mean TSP (total suspended particulate) recorded in Lumby for the period 1983 to 1990 was 70 ug/m^3. The Federal Government has set the desirable level for TSP at 60 ug/m^3. The mean TSP measured during the same period in the industrial and wood processing centres of Port Alberni, Kamloops, Trail, Williams Lake, Smithers, and Prince George were 38, 40, 45, 65, 41, and 54 ug/m^3, respectively (Richardson, Jensen and Bryan 1991). The TSP levels in Vernon were also high (65 ug/m^3) but was only 35 ug/m^3 in both Kelowna and Penticton.

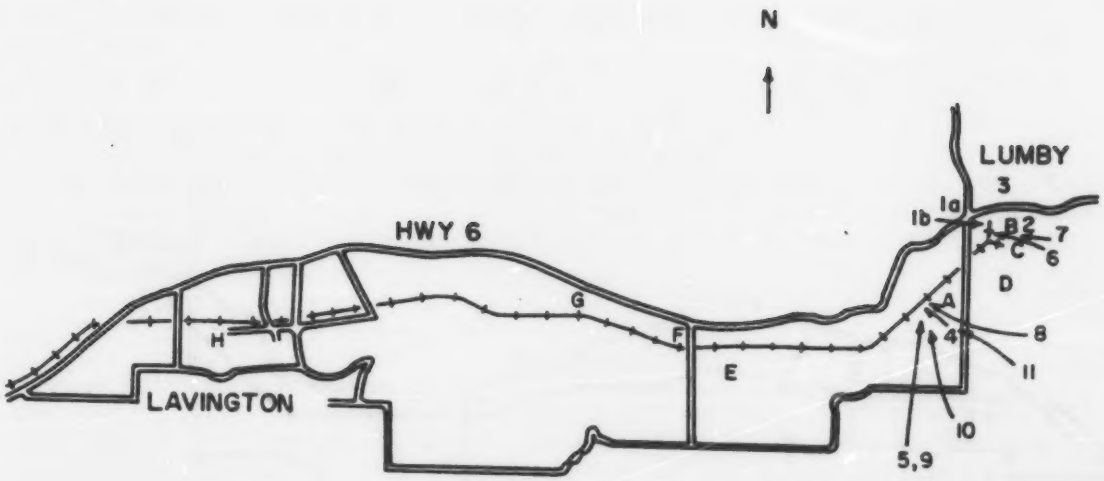
At six of the seven B.C.E. (British Columbia Environment) dustfall sites for which there are nearly continuous records from 1975 to 1990, over 80% of dustfall measurements exceeded the provincial A air quality objective of 1.75 mg/dm^2/day (Richardson, Jensen and Bryan 1991). Twenty percent of the measurements exceeded this limit at the seventh site (Lumby - Charles Bloom School). In Vernon, Kelowna, and in Penticton very few dustfall measurements exceeded the provincial A objective (Richardson, Jensen and Bryan 1991).

1.1 Study Area

Data collection sites were scattered along approximately 15 km of the Lumby valley. They extended from a site about 5 km east of the village of Lumby, to a site just west of the Lavington Planer Mill (see Maps 1 and 2).

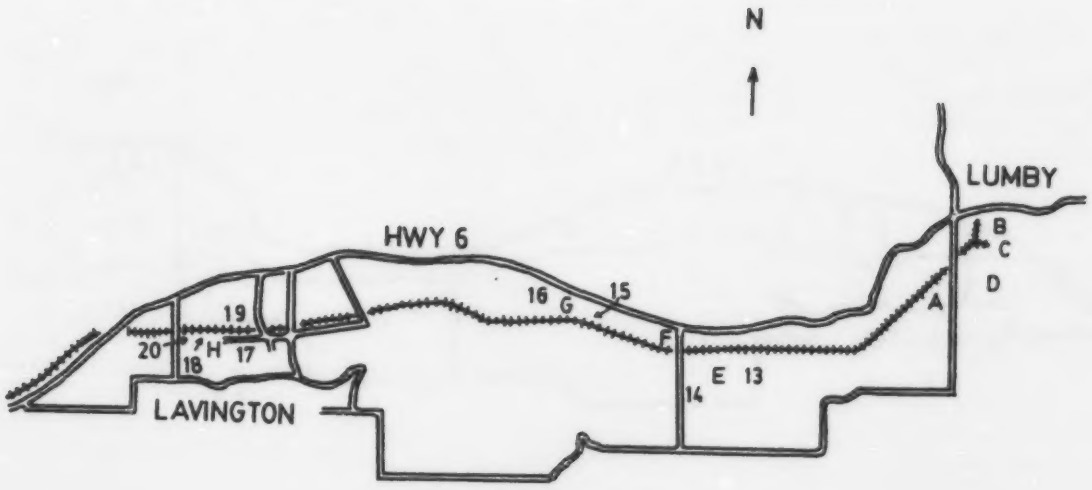
Map 1. Sketch map of Lumby showing location of burners (A - D) and dustfall samplers (1 - 11).

A) Weyerhaeuser, B) Bell Pole Sawmill, C) Fletcher Challenge, D) Bell Pole, 1a) Lumby Hotel, 1b) Lumby Home Furnishings, 2) Ruesch Residence, 3) Charles Bloom School, 4) Lumby South, 5) Weyerhaeuser West, 6) Duteau 1, 7) Duteau 2, 8 - 11) Weyerhaeuser 1 - 4



Map 2. **Sketch map of Lumby-Lavington area showing location of burners (A - H) and sampling sites west of Lumby (13 - 20)**

A) Weyerhaeuser, B) Bell Pole Sawmill, C) Fletcher Challenge, D) Bell Pole, E) Gorman Bros., F) R.V. Schmidt, G) Riverside Forest Products, H) Lavington Planer Mill, 13) Gorman's East, 14) Gorman's West, 15) Riverside East, 16) Riverside West, 17) Lavington P.M. East, 18) Lavington P.M. West, 19) Lavington East, 20) Lavington Harber



1.1.1 Meteorological Conditions

There are no recording stations in the Lumby - Lavington area for wind strength and direction, presumed to be two of the major determinants of dust dispersion. Extrapolation from data gathered in Vernon is probably meaningless. Environment Canada staff suggest that the wind patterns should be predominantly westerly or easterly, with the former less frequent, stronger, more gusty, and typically associated with major storms. The topography around Lumby is sufficiently complex that the east - west trend, which presumably adequately describes the conditions in Lavington, is too simplistic for the mill sites in the village of Lumby (see Reid 1990).

Environment Canada describes the climate at Lumby as cold continental with light precipitation. April is the driest month and December the wettest. Perhaps of greatest relevance are the ground based inversions in the valley 60% of spring and winter mornings, 70% of fall mornings, and 80% of summer mornings. These inversions rarely persist into the afternoon except in winter when they occur on one of four days. Such inversions tend to trap smoke from the burners, producing obvious, visual pollution.

1.2 Air Quality Sampling

Four types of samplers were used in this study: B.C.E. dustfall, permittee dustfall, B.C.E. Hi-vol samplers, and permittee burner monitoring. Each sampler and type of data is described in the following sections.

a. B.C.E. dustfall samplers.

A dustfall canister is an open vessel, containing a liquid medium, that traps all particles dropping into it. Because of the rapid settlement rate of larger particles, canisters are selective for particles greater than 20 to 40 um. The collecting medium is removed each month (a two-week operating period has been used at many permittee sites) for analysis, and the canister recharged.

Dustfall analysis consists of determining the total mass of particles falling through the known area of the canister mouth in a fixed time. The portions that are soluble and insoluble are measured separately, as are the soluble and insoluble ash components (the portions remaining after the organic component has been burned off). The total dustfall and combustible dustfall are calculated from these measurements. The combustible fraction is meant to be an indication of the total dustfall that originates from sources that handle organic materials, such as saw mills, chippers, etc. The non-combustible portion is presumed to originate from sources such as road dust, ploughing, or industrial plants handling inorganic material.

Siting of B.C.E. canisters reflects the dual need to monitor dustfall at source (e.g. around burners) and in population centres where it may be deposited (Maps 1 & 2, Table 1). Prior to 1989 these canisters were operated continuously throughout the year. Since January 1989, all but the Lumby Centre sampler, have been operated on a reduced schedule of two to four samples per year.

TABLE 1
B.C. Environment dustfall monitoring sites
(Lumby - Lavington area)

Site #	Site name and location	Date operated
0500131*	Lumby air study #1 - Lumby Hotel	71.07 - 76.07
0500132	Lumby air study #2 - Trailer Court	71.07 - 74.11
0500133	Lumby air study #3 - 1/2 Mile East	71.08 - 79.01
0500134	Lumby air study #4 - West (South)	71.08 onward
05001035	Lumby air study #5 - East Control	72.01 - 79.01
0500438**	Lavington air study #1 - East (relocated as 0500698)	75.04 - 78.01
0500439	Lavington air study - Centre (referred to as Lavington Harber)	75.04 onward
0500509	Lavington air study - West	76.02 - 79.08
0500653	Duteau Creek at Bell Sawmill	78.03 - 82.06
0500654	Duteau Creek at Railway Bridge	78.03 - 82.06
0500655	Lumby - Anton Ruesch residence	78.03 onward
0500698**	Lavington air study - East (relocated from 0500438)	79.03 onward
0500699	Lumby - Health Centre	79.03 - 79.09
0500700	Lumby - Chas. Bloom School (renumbered e206301)	79.02 onward
0500701	Lumby - Home Furnis ings (renumbered e206302)	79.03 onward
0500702	Lumby - Weyerhaeuser (renumbered e206303)	79.03 onward

* 0500131 and 0500701 collectively referred to as Lumby Centre.
**0500438 and 0500698 collectively referred to as Lavington East.

b. Permittee dustfall canisters.

These are similar to B.C.E. samplers except permittees are generally required to operate them for only a two week period in each month. They are usually located on the permittee property boundary on the east - west axis from the burner (Maps 1 & 2, Table 2). Siting therefore presumes a prevailing west - east air flow.

c. B.C.E. suspended particulate samplers (Hi-Vol samplers).

These measure the mass of suspended particles (TSP) in a fixed volume of air drawn through a filter. Such particles are smaller (0.3 to 30.0 um) and different in character to those settling into a dustfall canister. These samplers are normally operated for 24 hours every sixth day. The only suspended particulate sampler in this area is located on the roof of the Home Furnishings store in Lumby.

TABLE 2

Permittee dustfall sampling sites (Lumby - Lavington area)

Site #	Site name and location	Date operated
0500396	Fletcher Challenge	73.04 - 75.12
0500523	Lavington Planer Mill #1	74.05 onward
0500524	Lavington Planer Mill #2	74.05 onward
0500525	Lavington Planer Mill #3	81.02 - 81.04
0500526	Lavington Planer Mill #4	81.02 - 85.05
0500527	Riverside Forest Products - East	74.11 - 79.08
0500528	Riverside Forest Products - West	74.12 - 79.08
0500529	Gorman Brothers - East	74.12 - 79.05
0500530	Gorman Brothers - Office	74.12 - 79.05
0500541	Weyerhaeuser Lumby #1 - Office	73.12 onward
0500542	Weyerhaeuser Lumby #2 - West	73.12 onward
0500543	Weyerhaeuser Lumby #3 - SW	73.12 onward
0500544	Weyerhaeuser Lumby #4 - SE	73.12 onward
0500568	Bell Pole Lumby #1 - South	75.09 onward
0500569	Bell Pole Lumby #2 - East	75.09 onward

Note. Date operated shows the date of the first and last record on file and does not imply continuous operation through that time.

d. Permittee waste burner performance monitors.

Permittees are usually required to monitor the smoke emission from their burners. Initially this is done by hourly, visual estimates of the density of the smoke emitted from the burner (opacity), and corresponding temperatures measured at the burner outlet. If the permittee establishes a relationship between opacity and burner temperature, the monitoring obligation can be reduced to recording burner temperature only. Lumber mills that have been issued permits for discharges from woodwaste burners, and their permitted dustfall and opacity limits, are listed in Table 3.

1.3 Report Period

Data from January 1975 to the latest available (early 1990) were used in compiling this report. The current permitting process was initiated in 1973 and most of the mills were granted permission to discharge from woodwaste burners in 1974 and 1975.

TABLE 3

Lumby - Lavington area woodwaste burner permittees (including permitted discharge from burners)

Permit #	Company name	Dustfall limit *	Opacity limit
PA 1648	Fletcher Challenge**	1.75	>20% not more than 10% of day (3 of 30 min) Never > 40%
PA 1990	Bell Pole Co Ltd	"	"
PA 2001	Lavington Planer Mill Ltd	"	"
PA 2002	Gorman Brothers Ltd	"	"
PA 2008	Riverside Forest Products Ltd	2.90	"
PA 2019	Weyerhaeuser Canada	1.75	"
PA 3152	Bell Pole Co Ltd (Sawmill Div.)	"	"
PA 2026	R.V. Schmidt	No burning permitted	

* Dustfall limit in mg combustible dust/dm^2/d.
** Fletcher Challenge permit cancelled May 1989.

Data were collected for varying parts of the report period at different sites (see Tables 1 and 2). Information from sites operated for less than four years is not included unless it has some particular relevance to the discussion on air quality in this area. In 1988, because of the high cost involved, the B.C.E. reduced their sampling schedule to 4 months per year. The samplers were operated from January to April each year, as this is the period in which dustfall is at a maximum. Caution must be exercised in making inferences from incomplete data sets, or where sampling methods have been changed.

1.4 Data Sources

Data were drawn from four sources within the B.C.E. files:

a) System for Environmental Assessment and Management (SEAM) files from September 1983 onward.

b) Environmental Quality Information System (EQUIS), with information prior to September 1983.

c) permit files, containing reports on opacity, burner temperature, and burner operation and condition as witnessed by B.C.E. technicians during routine site inspections, and;

d) permittee data files containing information on dustfall, opacity, and burner operating temperatures. These records are a condition in the Waste Permit.

1.5 Parameters Used

Discussions of dustfall will centre on the combustible fraction since this is the standard parameter for setting limits for emissions from wood processing plants. The assumption is that unburned particles from burners operating at less than optimal temperature, and other fugitive wood particles, are the major pollutants. Dustfall measurements are expressed as the geometric mean of the values recorded in a defined period, or as the percentage of measurements from a given period that fall within each of the air quality objectives (see Appendix A) established by the British Columbia Provincial Government.

The general public's perception of air quality is probably determined by dust deposited on such surfaces as washed clothes or cars, and by the smoke haze lingering in the valley. It is unlikely that they will make a distinction between combustible dust from burners and non-combustible dust from other sources. Hence the discussion will also use total dustfall and total suspended particulates in trying to analyze the contribution of the burners to the overall problem of air quality. It should be also borne in mind that the provincial objective levels are expressed as total dustfall.

Opacity is a direct measure of the "thickness" of smoke emitted from the burners. It is the percentage of light that would be otherwise visible to an observer but that fails to pass through the column of smoke. This was previously recorded as a Ringlemann or R number, determined by comparing a smoke plume to a graded series of reference cards. R1 was equivalent to an opacity of 20%, R2 to 40% etc. Burner temperature is the most direct, least subject to error, and most efficient of the methods used to monitor burner performance. It is also the most difficult to analyze. The report comments on the usefulness of this measure and its relationship to opacity and dustfall.

1.5.1 Data analysis

All data were analyzed using an SPSS/Pro statistical package. Significance levels are included in the text, and a level of 0.05 used for rejection of the null hypothesis that differences between sets of observations could be explained on the basis of random chance.

Because dustfall measurements are not distributed normally (in the shape of a "bell curve") most of the statistical analyses use non-parametric methods (see Siegel 1956, and Sokal & Rohlf 1969 for discussions on the strength and validity of non-parametric methods). The geometric mean is used as the measure of central tendency. This is usually lower than the arithmetic mean for data skewed to the left (as is dustfall data), because it is influenced less by the few extremely high values.

A comparison of data collected from 1975 to 1983 with that collected from 1983 onward was used to assess potential changes in dustfall. This time period was used as being long enough to mask spurious variations. The Mann-Whitney U test used to compare the two periods ranks (gives a number 1 to the highest value in the total set, 2 to the second highest, etc.) all the data values. It then compares the average rank of the two sub-sets (in this case the two time periods).

Comparisons of time periods other than those mentioned above have been made where some particular event, such as closure or changes to a burner, seemed to warrant it. Computation of a Spearman rank coefficient was used to test for a temporal correlation between sets of data. This is computed by separately ranking the two sets of values and then comparing the differences in rank between corresponding values in each of the sets. For example, if yearly dustfall at Lumby Centre and Lumby South are positively correlated we would expect the same years at each site to rank highest, the same years to be ranked lowest, etc. If they are negatively correlated we would expect the high value at one site and the low value at the other to occur in the same year.

2. RELATIONSHIPS BETWEEN DUSTFALL AND OTHER FACTORS

2.1 Weather Effects

It was assumed, *a priori*, that precipitation would have a scrubbing effect and remove fugitive dust from the air almost at source, and that higher temperatures (and presumably drier ground conditions) would lead to an increase in non-combustible dust from vehicle and agricultural activities. The first assumption was not upheld by an analysis of data from Lavington Harber. There was no demonstrable relationship between monthly precipitation and either combustible, non-combustible, or total dustfall (Spearman Rank Correlation coefficients, -0.05 P=0.59, -0.02 P=0.79, and -0.06 P=0.54, respectively).

Combustible dustfall was inversely related to mean monthly temperature (Spearman Rank Correlation 0.21, P=0.02). The relationships between non-combustible and total dustfall, and temperature were not statistically significant (Spearman Rank Correlation coefficients, -0.18 P=0.054, and -0.08 P=0.40, respectively). The most probable explanation is that high burner temperatures are difficult to achieve in the winter months because of wet or snow covered waste. However, domestic wood-burning heaters may contribute to this correlation.

2.1.1 Wind Effects

There were positive correlations between combustible measures at all the Lumby area B.C.E. samplers (Spearman rank correlations, P <0.001 for all pairs). These correlations are a measure of how each site fluctuates with the other and suggest a high level of consistency in the measurements. Yet there is no simple, intuitive reason for this consistent positive correlation. Sites on opposite sides of a dust source, relative to the prevailing wind direction, could be expected to be inversely related. A direct correlation would only be expected if dust was distributed concentrically from the source and there was no tendency for it to drift preferentially in one direction.

Non-directionality of dispersal may result from winds too light to act as a dispersal agent, or because the distribution of wind directions in each monthly sampling period is random. Alternatively, a quantity of dust generated on a windy day could be spread over a larger area than a similar amount generated on a calm day, and the results from a particular sampler, depending on its distance from the source, may be dominated by dustfall on calm days. Regardless of the cause, the empirical evidence from Lumby indicates a lack of directionality in dust dispersion. Reid (1988) also attempted to determine the effect of wind on deposition of dust in samplers located around the Bell Pole burner, but was unable to show any consistent patterns relating dustfall to wind strength speed or direction.

2.2 Dustfall and Suspended Particulates

Four of the Lumby sites (Weyerhaeuser West, Charles Bloom School, the Ruesch residence, and Lumby Centre) showed a positive correlation between combustible dustfall and suspended particulates measured at Lumby Centre (Richardson & Jensen 1989). Lumby South showed no correlation (Spearman Rank correlations, probabilities 0.014, 0.012, 0.050, 0.007, and 0.518, respectively). No similar correlation was found between dustfall at these same sites and suspended particulate levels in Vernon.

2.3 Distance from Burner

Dustfall decreases with increasing distance from the burners. The relationship between median combustible dustfall, for all samplers operated from 1981 to 1988, and distance from the nearest burner is described by the linear function

dustfall ($mg/dm^2/day$) = 0.034 + 0.57(1/km to burner)
(R squared = 0.40, P = 0.006)

2.4 Inter-Site Correlations

2.4.1 Lumby - Lavington correlations

There was no general pattern to the relationships between dustfall at Lumby and at Lavington (Table 4), with some pairs varying directly, some inversely, and some unrelated.

TABLE 4

Correlation coefficients between dustfall measured at Lumby and Lavington air sampling stations
Sample size (in brackets) and significance levels below

Lumby site	Lavington East	Lavington Harber
Lumby centre (combustible dust)	-0.116 (n=109) P = 0.07	0.157 (n=106) P = 0.017
Lumby centre (suspended part.)	-0.254 (n=67) P = 0.003	0.005 (n=67) P = 0.953
Chas. Bloom School	-0.082 (n=93) P = 0.249	-0.086 (n=89) P = 0.234
Ruesch residence	-0.109 (n=98) P = 0.115	0.053 (n=99) P = 0.444
Lumby South	-0.044 (n=116) P = 0.484	0.170 (n=117) P = 0.007
Weyerhaeuser B.C.E.	-0.142 (n=93) P = 0.045	0.149 (n=89) P = 0.039

2.4.2 B.C.E. - Permittee Sampler correlations

In comparison to the strong correlations between B.C.E. sampler results, there was no correlation between B.C.E. and permittee results from samplers located around the same burner. This was so even for B.C.E. and permittee samplers located within a few meters of each other (e.g. Weyerhaeuser West and Weyerhaeuser #3, or Lumby South and Weyerhaeuser #4, Spearman Rank Correlations P = 0.987, and 0.957, respectively).

The meaning of these correlations is obscure without a more detailed model of dust and suspended particle generation, distribution, and settlement. They do suggest that trends at

least could be monitored by a single sampler in Lumby and one in Lavington. Whether such a scheme is adopted or not, there is still a need to confront the problem of standardising the siting, sample periods, and analytical methods used in sampling dustfall.

3. SITE SPECIFIC COMMENTS

The data are presented in five sections:

i) Lumby town-site - this is the greatest concentration of people likely to be affected by emissions from the burners and therefore the B.C.E. has concentrated much of its sampling in this area.
ii) Weyerhaeuser Mill - completeness of the dustfall record is the sole reason for singling out Weyerhaeuser from the other three mills in close proximity to Lumby.
iii) Other Lumby mills
iv) Riverside - Gorman Brothers
v) Lavington Planer Mill

The last two groups are spatially distinct from each other and from the Lumby mills.

3.1 Lumby Town Site

The centre of Lumby (corner of Vernon St. and Shuswap Ave.) is 375 m WNW of the old Bell Sawmill burner site, 450 m NW of the Fletcher Challenge burner, 750 m NNW of the Bell Pole burner, and about 950 m NNE of the Weyerhaeuser burner. Unfortunately, the control site (0500135) was operated for only four years, but it clearly indicates (Figure 1) that dustfall 5 km to the east of the town is similar to that at other sites not associated with a recognized emission source.

Some portions of the town are subject to levels of combustible dustfall alone that far exceed the provincial objectives. At Lumby Centre (Figure 2) 20.5% of all observations between 1975 and 1987 were above 1.75 mg/dm^2/day. At the Ruesch residence, which is 300 m to the NNE of the Fletcher Challenge burner, over 65.5% of the measurements were above this level (Figure 3). In contrast, combustible dustfall at Charles Bloom School, 650 m N of the Fletcher Challenge burner was never more than 1.75 mg/dm^2/day.

A comparison of the frequency distribution of combustible dustfall measures (classed as <1.75, 1.75 - 2.90, or >2.90 mg/dm^2/day) before 1984 and for 1984 to 1989 showed no significant change either at Lumby Centre (Chi-square = 1.01, df = 2, p = 0.35) or at the Ruesch residence (Chi-square = 2.65, df = 2, P = 0.45). However, the same analysis of total dustfall at the Lumby Centre site (Table 5) did show a significant change (Chi-square = 6.86, df = 2, P = 0.03), with fewer months exceeding the provincial objective B level of 2.9 mg/dm^2/d.

Figure 1. Yearly combustible dustfall for Lumby Centre, the Ruesch Residence, Charles Bloom School, and Lumby East control.

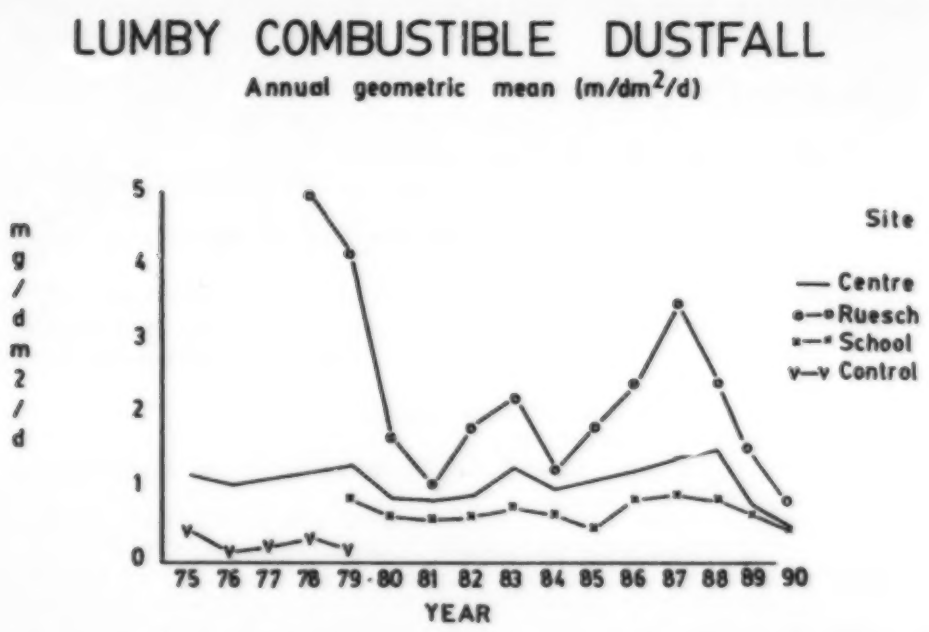


Figure 2. Percentage of combustible dustfall measurements each year at Lumby Centre exceeding B.C. provincial air quality objective levels of objective A (1.75 mg/dm^2/day) or objective B (2.90 mg/dm^2/day).

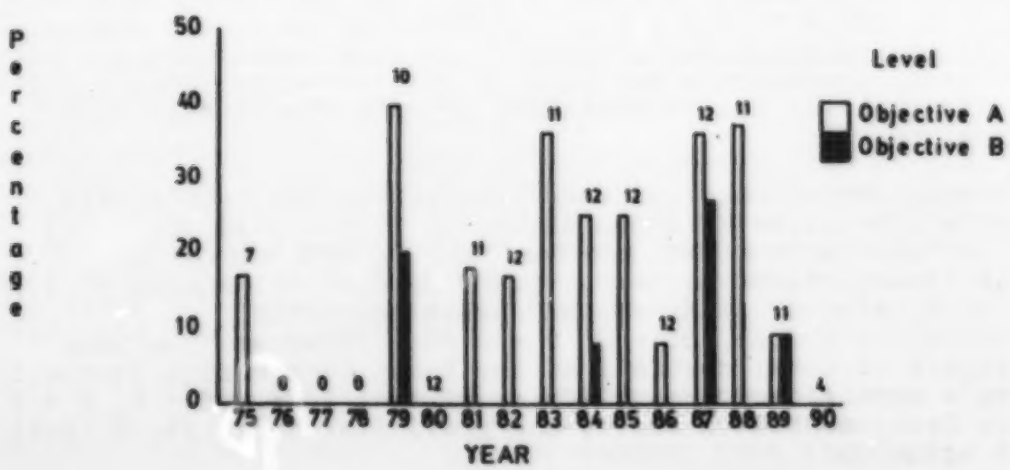


Figure 3. Percentage of combustible dustfall measurements each year at the Ruesch Residence exceeding B.C. provincial air quality objective levels of objective A (1.75 mg/dm²/day) or objective B (>2.90 mg/dm²/day).

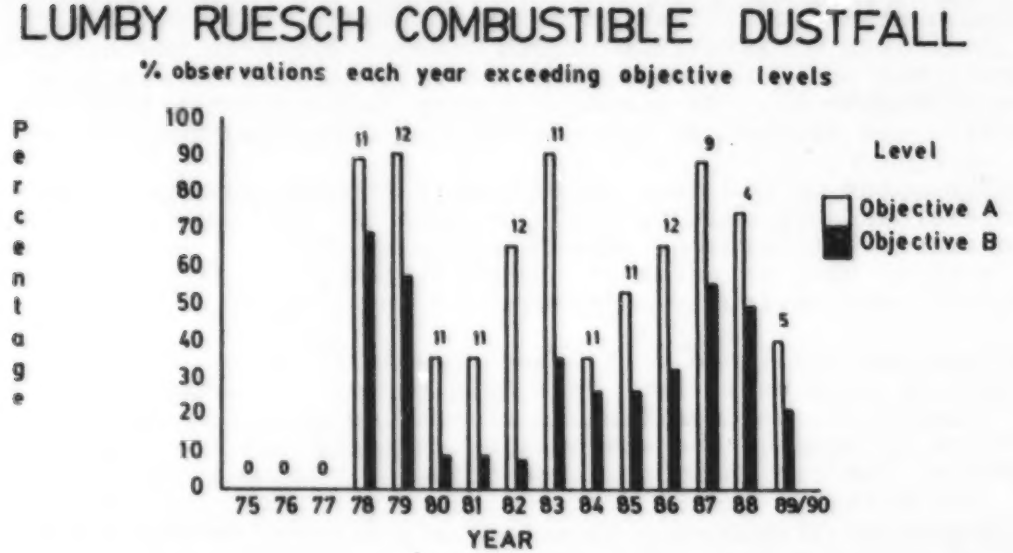


TABLE 5

Comparison of the frequency distribution of total dustfall measures at Lumby Centre from 1975-83 and 1984-89

Years	# of observations <1.75	1.75-2.9	>2.9
1975-83	12	35	29
1984-89	15	22	9

The same trend is observed in the TSP data (Figure 4). Since 1984 the majority of values fall within the provincial objective A level of <150 ug/m³ for a 24 hour continuous monitoring period. This represents a significant change from the years prior to 1984. Although dust is a considerable nuisance, suspended particulates probably constitute a greater health hazard to people living in the area as they are more readily absorbed through the skin and lungs (Chambers 1968).

The restriction of permit discharge limits to combustible dustfall implies, in practice if not by intent, that unburned material emitted from a woodwaste burner is the sole contribution to air pollution made by lumber mills. Yet at Lumby Centre there

is a significant correlation between combustible and non-combustible dustfall (Spearman rank correlation, N = 121, P = 0.018). This suggests a relationship between the formation of non-combustible and combustible dust, or their transport and deposition.

During a strike by forest industry employees from July 22nd to December 10th of 1986 that closed several mills in the area, both combustible and non-combustible dustfall dropped to very low levels (Figure 5). No comparable drop in non-combustible dustfall was evident at other mills unaffected by the strike.

Less than 50% of the dust collected in the two Lavington WMB samplers, and approximately 60% at each of the Lumby sites, was combustible (Richardson, Jensen and Bryan 1991). Thus examining air quality only in terms of the permitted parameter, combustible dustfall, may seriously underestimate any problem.

The Fletcher-Challenge mill ceased operation March 31, 1989. The burner was used until late June 1989 to burn material as the mill was dismantled, and was finally dismantled itself. The obvious question is whether the air quality in Lumby has improved as a result of the Fletcher-Challenge closure. Table 6 compares the data collected in the 12 months since March 1989, with that for the preceding 12 months. There are significant reductions in each of the main parameters considered in this report.

Figure 4. Percentage of daily TSP observations each year at Lumby Centre exceeding B.C. air quality objective levels A,B,C, (120, 150, 200 ug/m^3, respectively).

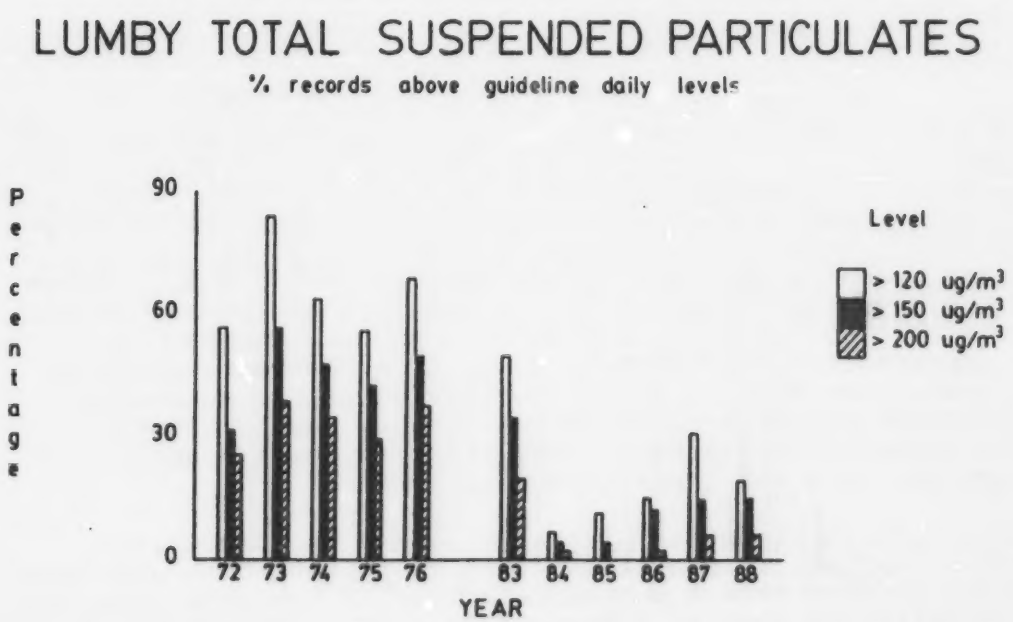
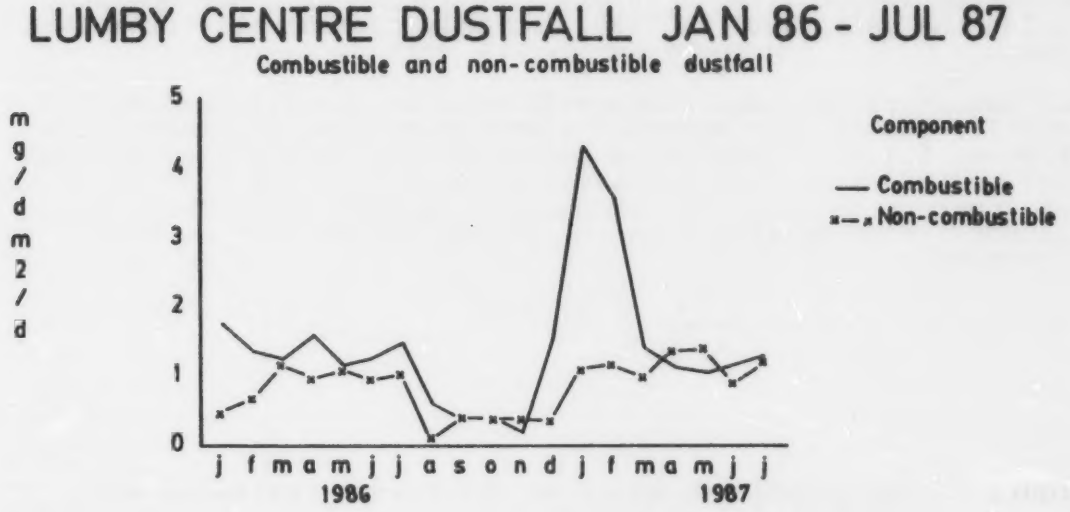


Figure 5. Comparison of the non-combustible and combustible dustfall at Lumby Centre before, during, and after the strike closure of local mills between July 22, 1986 and Dec 10, 1986.



Samplers close to other active burners, and those in Lavington, also showed decreases in dustfall since March 1989. Most of these have been on the reduced sampling schedule and direct comparisons of the two time periods are questionable. However, the three samples are taken in the period of maximum dustfall settlement, which strongly suggests these decreases are real.

TABLE 6

Comparison of the means, and frequency distributions of combustible dustfall, non-combustible dustfall, and TSP in the 12 month periods before and after closure of the Fletcher Challenge Mill.

Parameter	before/after 89.03.31	mean	number observations <1.75 ($mg/dm^2/d$)	1.75-2.90	>2.90
combustible dustfall	before	1.47	12	5	1
	after	0.58	10	0	0
non-combustible dustfall	before	1.12			
	after	0.50			
			<150 (ug/m^3)	150-200	>200
total suspended particulates	before	71.1	11	7	2
	after	59.8	6	5	2

3.2 Weyerhaeuser

There have been six dustfall canisters located on or close to the perimeter of the Weyerhaeuser property. Two were operated by B.C.E. (Lumby South and Weyerhaeuser West) and four by the permittee (Weyco 1, 2, 3, & 4). The latter were not operated during the years 1981 to 1985, and only sporadically from 1986 to 1988.

All canisters recorded a dramatic peak in dustfall around 1977-78, and current dustfall seems lower than in those years (Figures 6,7,8). However, a comparison of data collected from 1975 to 1983 with that collected between 1984 and 1987 shows that any apparent decrease in combustible dustfall over these years is illusory (Mann-Whitney U tests, probabilities 0.15 to 0.93).

Figure 6. Combustible dustfall at the Ruesch Residence and productivity at the Fletcher Challenge mill from 1978 to 1987.

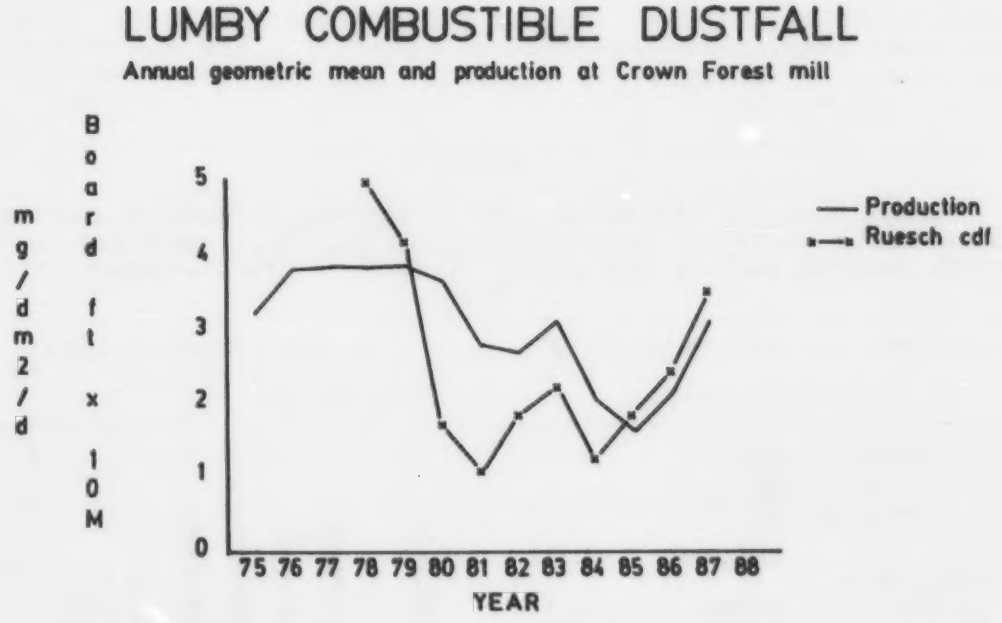


Figure 7. Annual combustible dustfall at Lumby South and Weyerhaeuser West samplers, between 1975 and first three months of 1990.

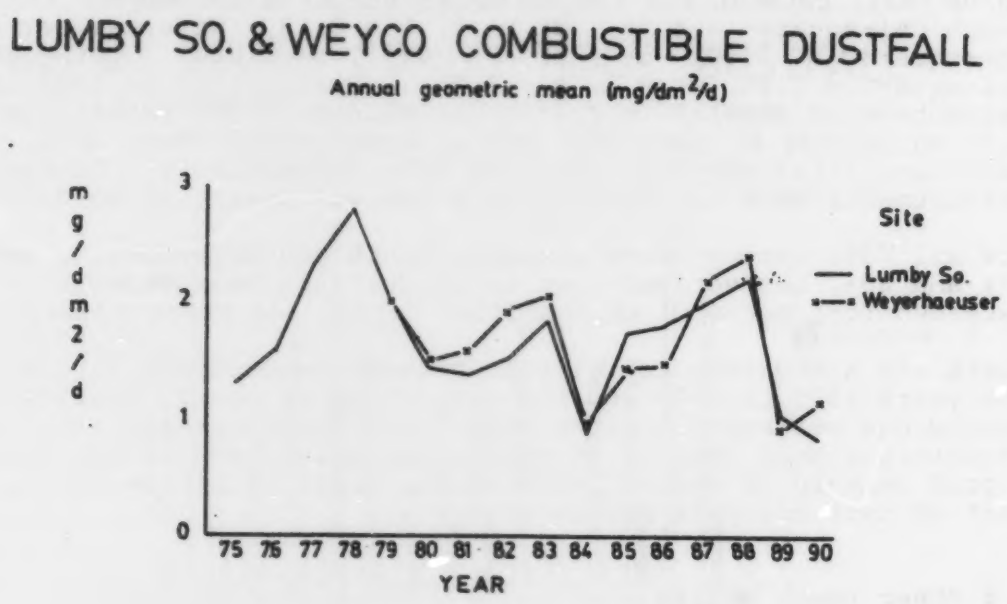
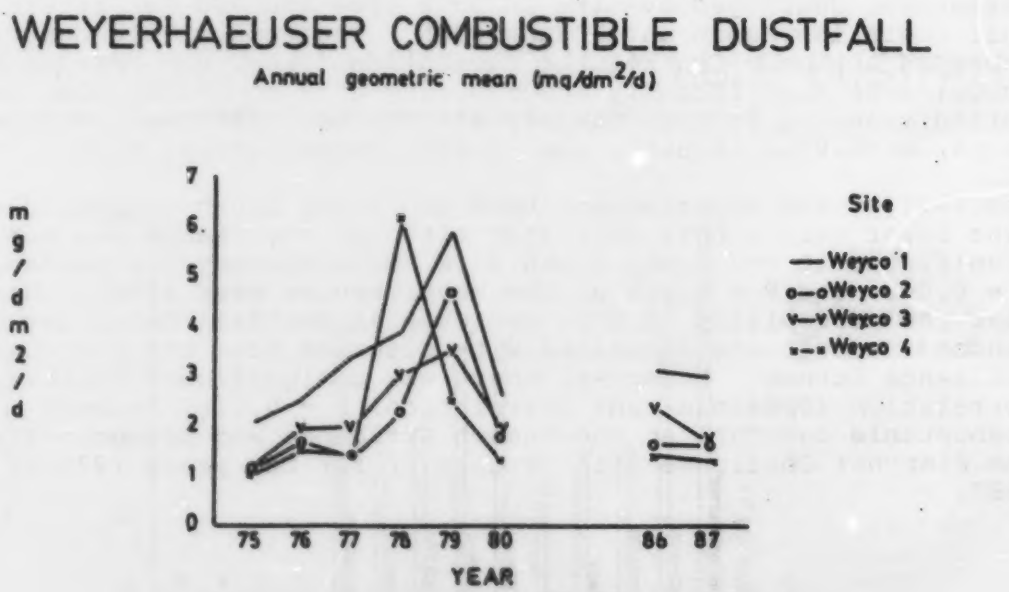


Figure 8. Annual combustible dustfall at the four Weyerhaeuser permittee samplers between 1975 and 1988.



A comparison of the distribution of observations by objective levels (Figures 9 and 10) showed no significant changes in the frequencies of observations (<1.75, from 1.75 to 2.9, and >2.9 $mg/dm^2/day$) between the two periods 1975-83 and 1984-87; (Lumby South Chi-square = 4.06, df = 2, P = 0.13, Weyerhaeuser West Chi-square = 1.50, df = 2, P = 0.47, permittee sites combined Chi-square = 3.95, df = 2, P = 0.25). During 1984 to 1989 the percentage of dustfall measurements exceeding the permit limit of 1.75 $mg/dm^2/day$ at the Lumby South, Weyerhaeuser West, and permittee sites was 52%, 50%, and 50%, respectively. Of ten measurements made in 1989/90, only one was over 1.75 $mg/dm^2/d$.

For all data through 1988 at Lumby South and Weyerhaeuser West, 91% and 89%, respectively, of total dustfall measurements exceeded 1.75 $mg/dm^2/d$ (Richardson, Jensen and Bryan 1991).

There was a negative correlation between combustible dustfall for the years 1975 to 1979 and the proportion of hourly opacity recordings per month greater than 40%. While opacity is certainly a good measure of visual pollution, and it may well be a good measure of burner performance, it is of little use in the sort of data analysis presented here.

3.3 Other Lumby Mills

The presence of four burners (Fletcher Challenge, Bell Pole, Bell Pole Sawmill, and Weyerhaeuser) within each other's dustfall shadow makes it difficult to resolve an individual burner's contribution to the overall problem. Fletcher Challenge has not been required to monitor dustfall during the report period. This burner was destroyed by fire in June 1984 and did not return to full operation again until June 1985. The combustible dustfalls recorded at Lumby Centre, the Ruesch Residence, and Charles Bloom School were significantly lower during this shut-down than in the period spanning it from January 1980 to Dec 1988 (Mann-Whitney U tests, P <0.001, <0.0001, and <0.005, respectively; Figure 11).

Dustfall at the Weyerhaeuser West and Lumby South canisters was also lower during this shut-down although the change was not significant at the Lumby South site (Mann-Whitney U 1-tailed, P = 0.066 and P = 0.008 at the Weyerhaeuser West site). Note that the probability of this decrease in dustfall being due to random fluctuations increases with distance from the Fletcher Challenge burner. Moreover, there was a significant positive correlation (Spearman rank correlation, P = 0.016) between combustible dustfall at the Ruesch Residence and productivity at the Fletcher Challenge mill (Figure 6) for the years 1978 to 1987.

Figure 9. Percentage of combustible dustfall observations each year at the Lumby South sampler exceeding B.C. air quality objective level A (<1.75 mg/dm²/day) or objective B (>2.90 mg/dm²/day).

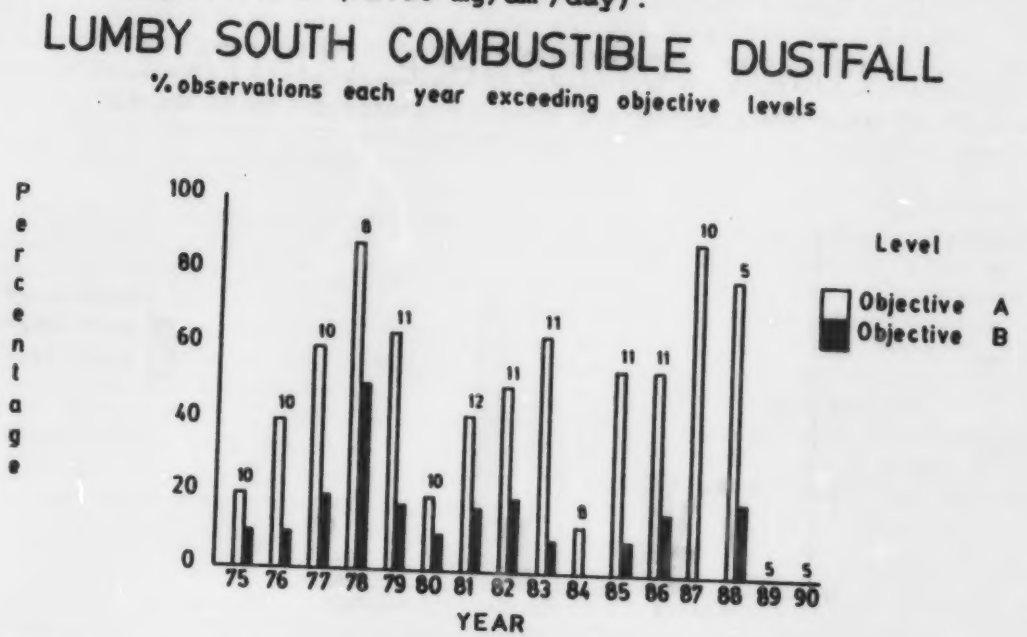


Figure 10. Percentage of combustible dustfall observations each year at Weyerhaeuser West sampler exceeding B.C. air quality objective level A (<1.75 mg/dm²/day) or objective B (>2.90 mg/dm²/day).

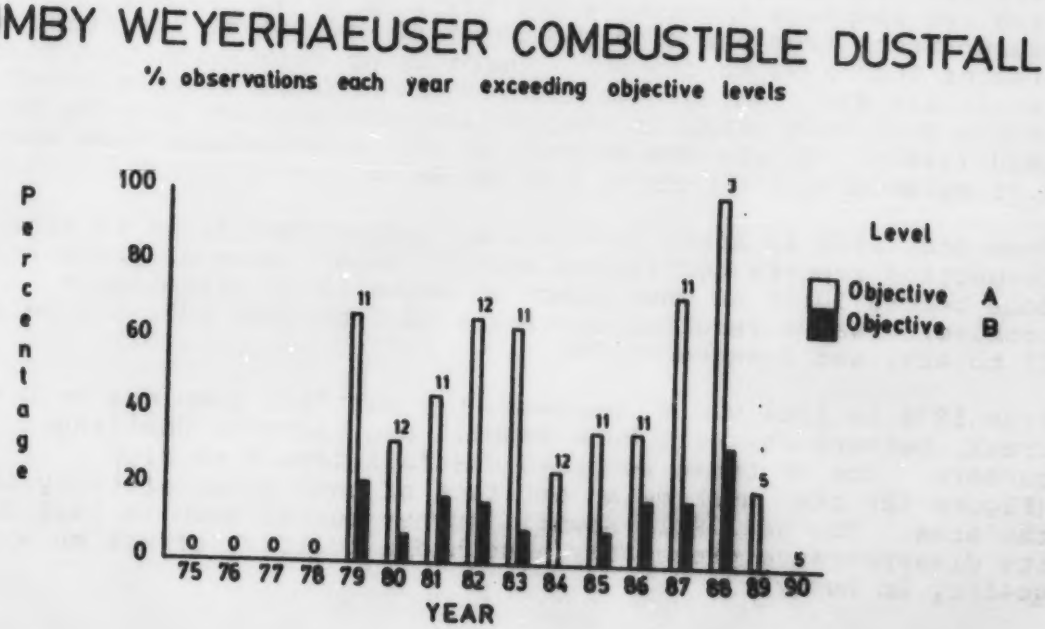
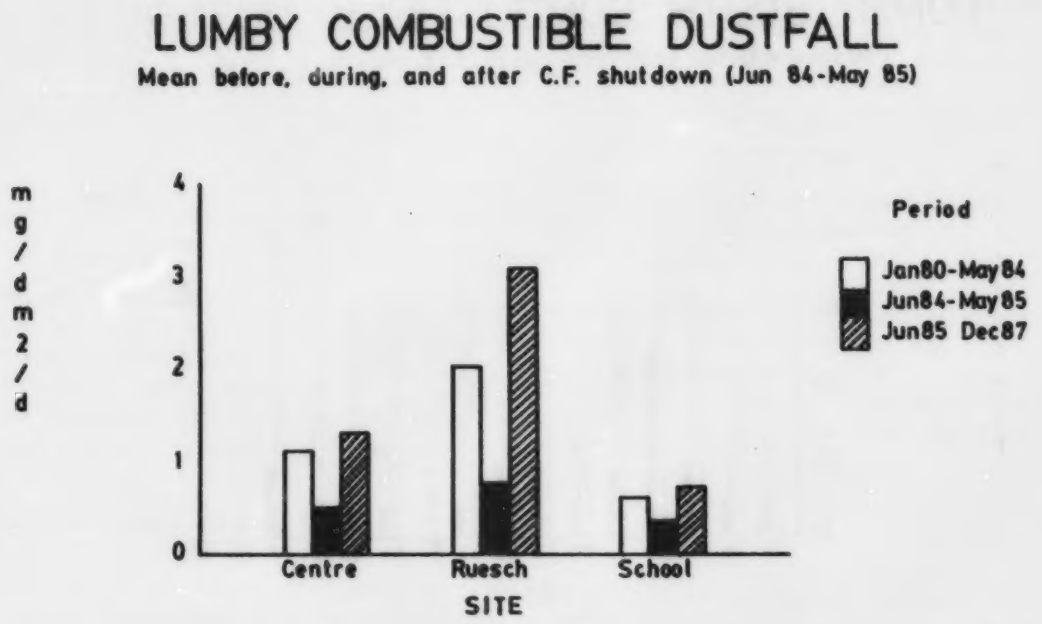


Figure 11. Comparison of the mean combustible dustfall at Lumby Centre before, during, and after shutdown of the Fletcher Challenge (C.F.) burner due to fire damage.



Data from the Bell Pole burner is incomplete, but of the data from two samplers operated since 1979, 32 of 41 (78.2%) measurements from one site and 33 of 40 (82.5%) at the other were greater than 2.90 mg/dm^2/day. There is no suggestion that these levels are diminishing. In 1988/89 three samplers were operated on the Bell Pole site, in conjunction with a study done by Peter Reid (1990). Ninety one percent of the observations were above 1.75 mg/dm^2/d and 75% above 2.90 mg/dm^2/d.

From Oct. 1975 to April 1987 B.C.E. technicians filed 26 site inspection reports containing opacity data. None of these were done before 10:00 am when start up smoke is an unavoidable problem. Twelve reported opacities of less than 20%, 5 were from 20 to 40%, and 9 exceeded 40%.

From 1978 to 1981 B.C.E. operated two dustfall samplers on Duteau Creek, between the Bell Pole Sawmill and Fletcher Challenge burners. One of these recorded dustfall levels so high (Figure 12) they must be an artifact of some other activity in the area. The Bell Pole Sawmill burner burned down in 1981 and its disappearance presumably also had a positive effect on air quality in Lumby.

3.4 Riverside and Gorman Brothers

B.C.E. has not monitored air quality in the vicinity of these plants. Riverside Forest Products maintained a dustfall monitoring program throughout the report period, but Gorman Brothers received permission to discontinue its program in 1981. Riverside Forest Products is the only mill in the area with a permitted waste burner discharge of 2.90 mg/dm^2/day combustible dust, this having been increased in 1978 from the initial permit level of 1.75 mg/dm^2/day.

In common with many other sampling sites in this area, there was a peak of dust deposition in 1977 (Figure 13). But at the Riverside West site, unlike most of the other sites, this level is topped by heavier dustfall in the 1980's. This represents a significant increase in combustible dustfall at this site in 1984-1987 compared to 1975-83 (Mann-Whitney U, $P < 0.001$). There is no similar increase at Riverside East (Mann-Whitney U, $P = 0.95$). This is not a true assessment of changes in dustfall at Riverside East site as the canister has been moved some 200 meters to the east, and further from the burner, with an increase in area used for the log sorting.

Figure 12. Annual geometric means of combustible dustfall at the two B.C.E. Duteau Creek samplers, and the Ruesch Residence 1978 to 1982.

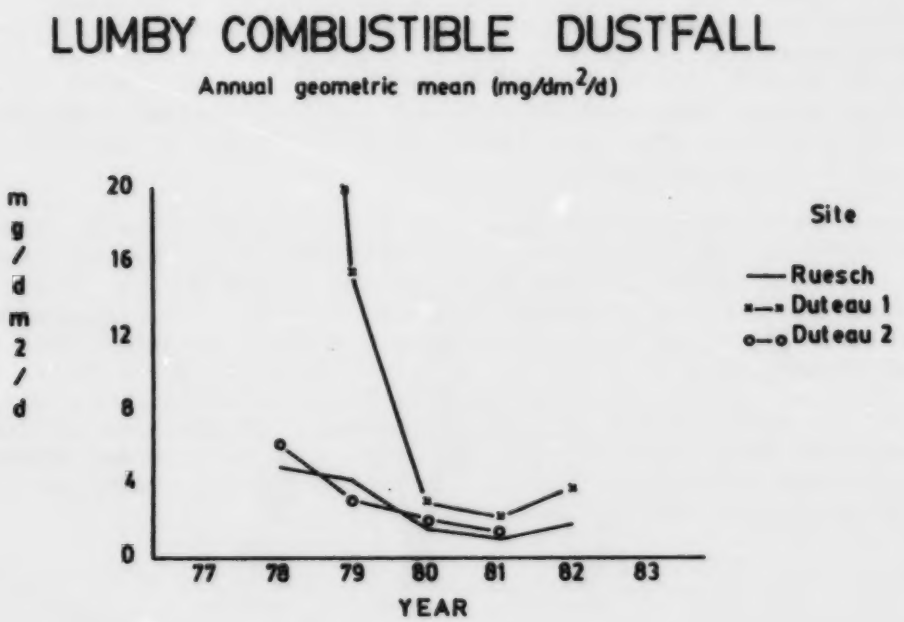
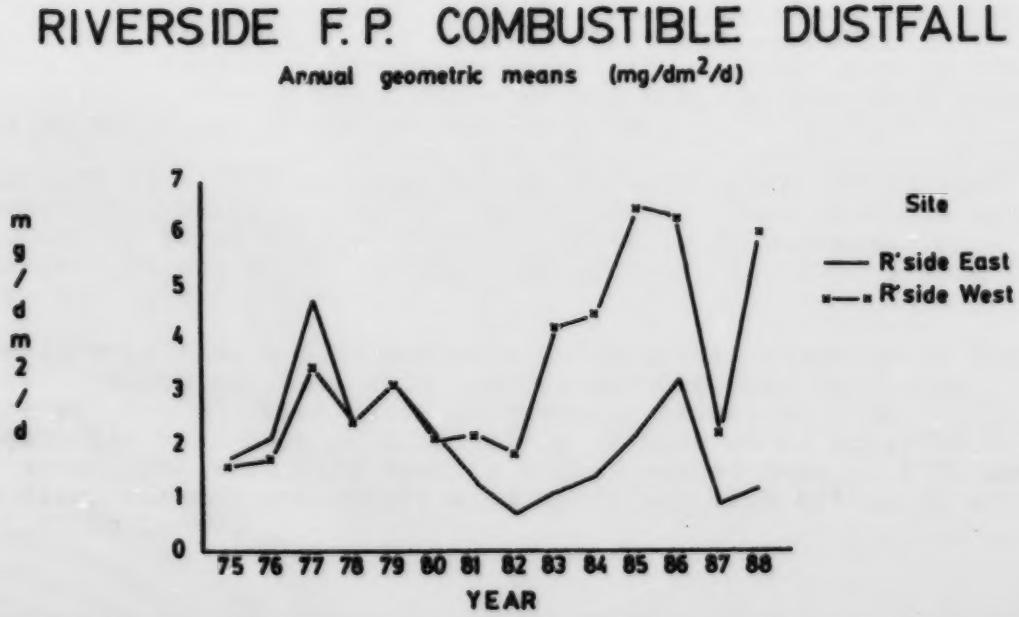


Figure 13. Annual geometric means of combustible dustfall at Riverside Forest Products samplers 1975 to 1988.



There was a corresponding increase between the two periods in the percentage of observations in the 1.75 - 2.9, and >2.9mg/dm²/day objective levels at Riverside West (Chi square = 9.35, df = 2, P = 0.009; Figure 14). From 1984 - 1988 eight of 37 observations (21.6%) fell in the 1.75 - 2.90 mg/dm²/day range, whereas 28 of 37 (75.6%) were greater than 2.9 mg/dm²/day. There was no significant change in the percentages at Riverside East (Chi- square = 4.32, df = 2, P = 0.115) where the corresponding proportions were 12 of 38 (31.5%), and 9 of 38 (23.2%) (Figure 15).

Temperature records for the Riverside burner from 1977 to 1979 indicate this burner was operating satisfactorily. Over a period of 29 months only 11 of the hourly temperatures were below 500° Fahrenheit, and 24 more below 600°, most of these being in the morning firing up time. These results are substantially in agreement with opacities recorded by B.C.E. technicians during site visits in the same period. There was no significant relationship between combustible dustfall and the number of hourly observations each month below these temperatures (Spearman Rank Correlation, P = 0.899).

Since 1979, the proportion of site inspection reports showing opacities above permitted limits has increased (7 out of 17 above 25%). The temperature recorder broke down in 1982 and was not repaired until early 1987 and no temperature/opacity data received during that time.

Little can be said regarding current levels or trends in dust deposition at Gorman Brothers pole plant. The median combustible dustfall at the Office sampler was only 0.6 mg/dm²/d, while at the East sampler it was 1.76 mg/dm²/d. During the years when dustfall was measured, only four of 50 results (8.0%) at Gorman Office sampler exceeded 1.75 mg/dm²/day, while at Gorman East sampler, 14 of 49 (28.6%) were between 1.75 and 2.9 mg/dm²/day, and 13 (26.5%) were greater than 2.9mg/dm²/day. Recent temperature records show Gorman burner to be operating at very low temperatures, rarely reaching even 500°F.

3.5 Lavington

Two B.C.E. and four permittee dustfall stations have been operated around the Lavington Planer Mill. The B.C.E. sites, Lavington Harber and Lavington East, are located approximately 250m west and 500m northeast of the mill burner, respectively. From April 1975 to October 1978 the easterly site was 50m south of its current position.

Figure 14. Percentage of combustible dustfall observations each year at Riverside West sampler exceeding B.C. air quality objective level A (<1.75 mg/dm²/day) or level B (>2.90 mg/dm²/day).

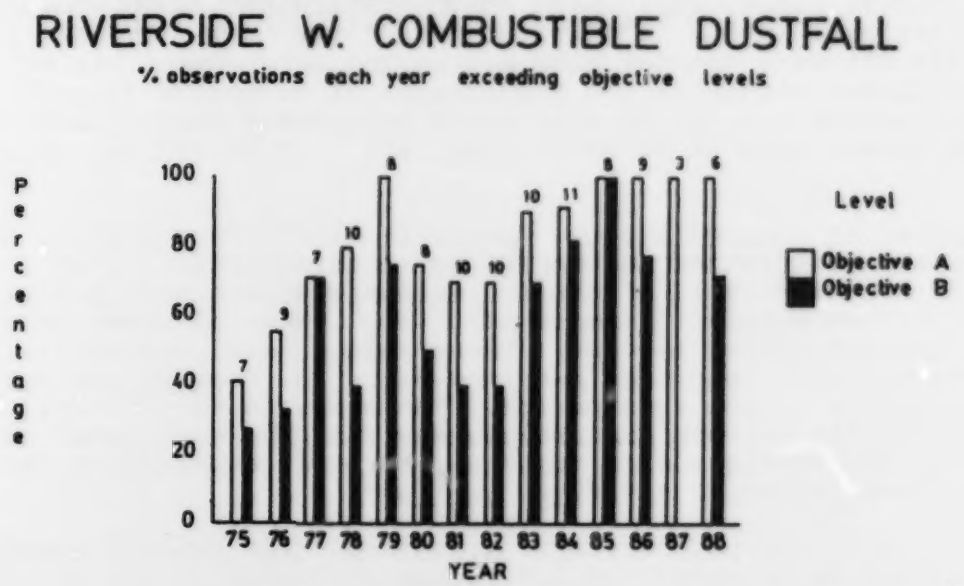
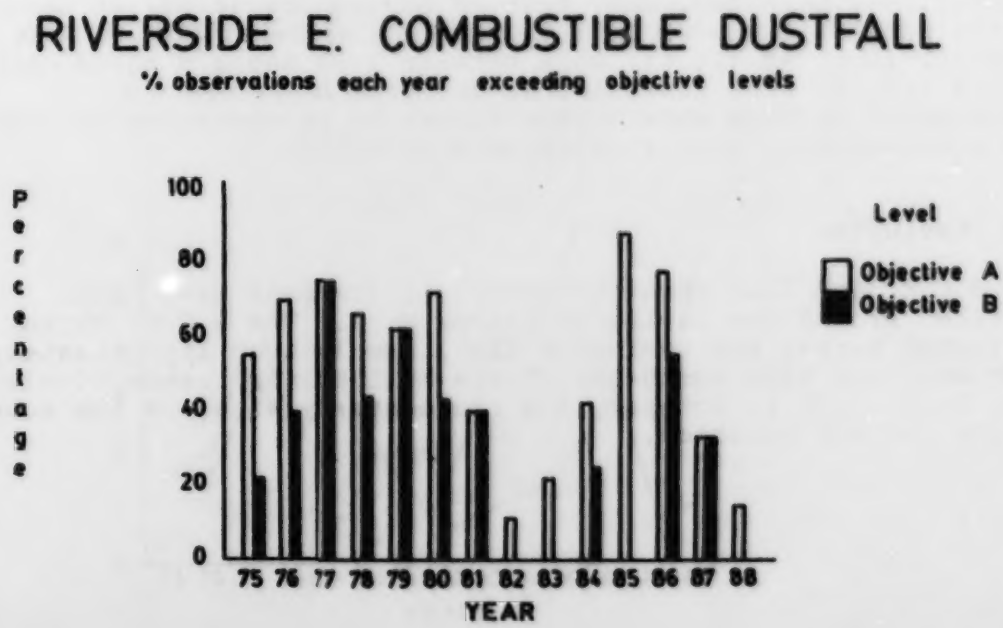


Figure 15. Percentage of combustible dustfall observations each year at Riverside East sampler exceeding B.C. air quality objective level A (1.75 mg/dm²/day) or objective level B (>2.90 mg/dm²/day).



The location and numbering of the permittee sites has changed twice during the report period. Two canisters were initially placed east and west of the burner at the property boundary. From February 1981 to March 1985 there were four canisters, one close to each of the corners of the property. In 1985 the permittee resumed sampling at the east and west sites only.

The Lavington data are examined specifically to determine if any changes in air quality resulted from the installation of the mill's new refractory burner in October 1985. Combustible dustfall west of the site is greater than to the east and the permittee samplers recorded higher dustfall than did the B.C.E. samplers (Figures 16, 17, 18). This could be a function of distance from the burner, although each site is probably influenced by different activities within the mill yard (e.g. the permittee western site is close to the rail-car sawdust loader). Non-combustible dustfall increased dramatically in 1986 to the west (Figure 16), and 1987 to the east (Figure 17) of the mill. Complaints regarding the road dust produced by heavy machinery working in the mill yard were received during this period.

3.5.1 Dustfall and the new burner

Combustible dustfall in the three years after installation of the new refractory burner is significantly less than before its installation (October 1985). This is so whether the comparison is made with dustfall over a period of three or ten years prior to installation (Mann-Whitney U, $P < 0.001$ in both cases). There was a simultaneous increase in non-combustible dustfall (Mann-Whitney U, $P = 0.038$ and 0.008 for the three and ten year comparisons, respectively). These off-setting trends resulted in no significant change in total dustfall with installation of the new burner.

The greatest increase in non-combustible dustfall at Lavington Harber occurred one year after installation of the burner and also at the Lavington east site. Therefore it seems unlikely that the changes in combustible and non-combustible dustfall are casually linked.

At the permittee west site, 89 of 107 observations (83.2%) were for combustible dustfall greater than 1.75 $mg/dm^2/d$, while at the east site, 54 of 108 (50.0%) records exceeded this level. At Lavington Harber there was a significant decrease in the number of monthly observations over 2.90 $mg/dm^2/d$ after the new burner started operating (Figure 19). Before October 1985, 55% of measurements were above this level compared to only 15% after.

Figure 16. Annuakl medians of combustible and non-combustible dustfall at the Lavington East sampler 1975 to April 1990.

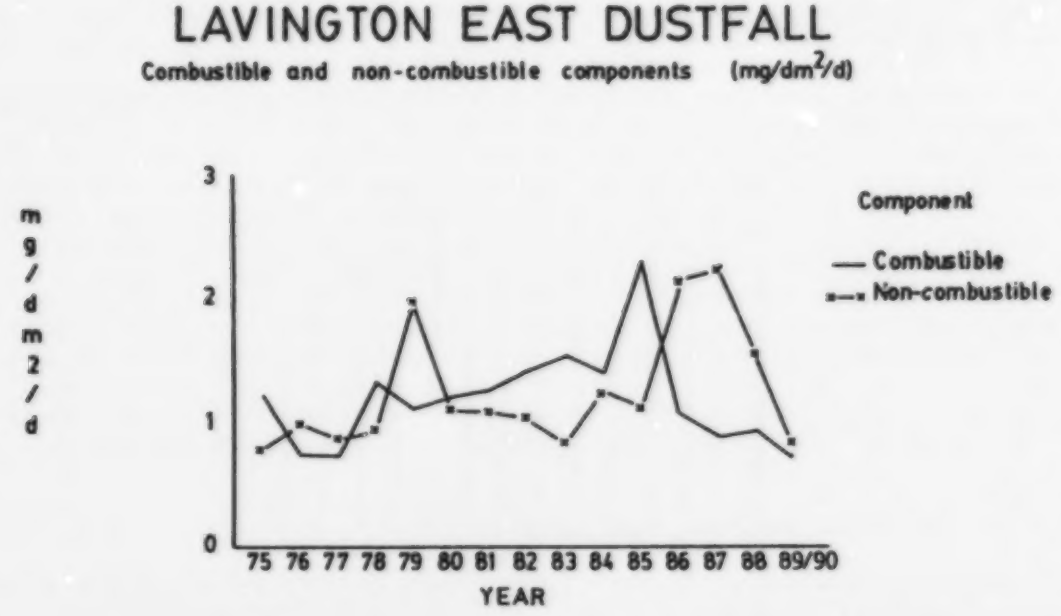


Figure 17. Annual medians of combustible and non-combustible dustfall at the Lavington Harber sampler, 1975 to April 1990.

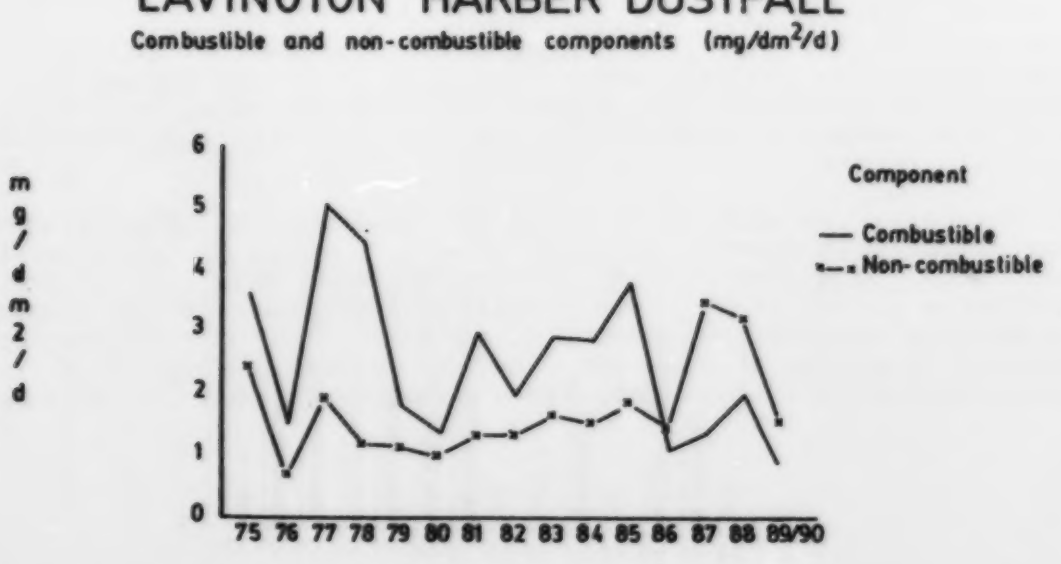


Figure 18. Annual geometric mean of combustible dustfall at the Lavington Planer Mill East and West samplers 1975 to 1988.

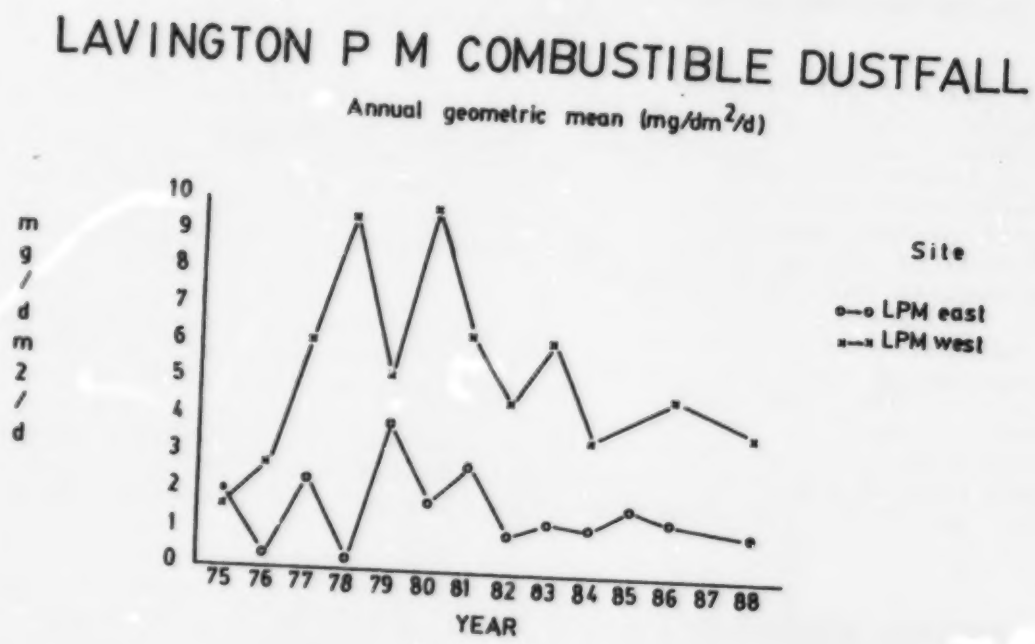
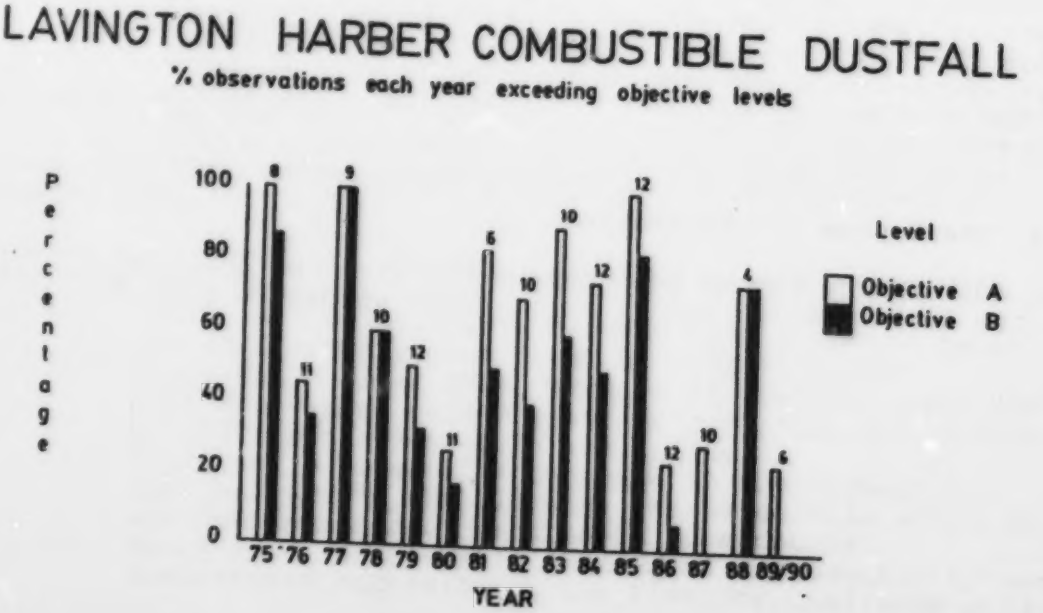


Figure 19. Percentage of combustible dustfall observations each year at the Lavington Harber sampler exceeding B.C. air quality objective level A (<1.75 mg/dm²/day) or level B (>2.9 mg/dm²/day).



There was no change in the frequency distribution of observations within the different objective levels at the Lavington East site, where both before and after 1985, 30% all observations exceeded 1.75 mg/dm^2/d (Figure 20).

3.5.2 Burner performance

Lavington Planer Mill compiled a nearly complete record of hourly temperature and opacity readings between 1975 and 1979. A temperature/opacity correlation performed by B.C.E. technicians in 1985 showed temperatures below 400° F corresponded to opacities of 60% or denser, and temperatures of 500°F and above to opacities of 20% or clearer.

Dustfall at each of the four sites around the mill was tested for a correlation with the number of hourly observations each month below 400, 500, and 600° F. The permittee western site, which is located closest to the burner (but is also suspected to be most susceptible to other yard activity), showed relationships between temperature and dustfall (Spearman rank correlations, P = 0.007, 0.019, and 0.033 for less than 400, 500, and 600°, respectively).

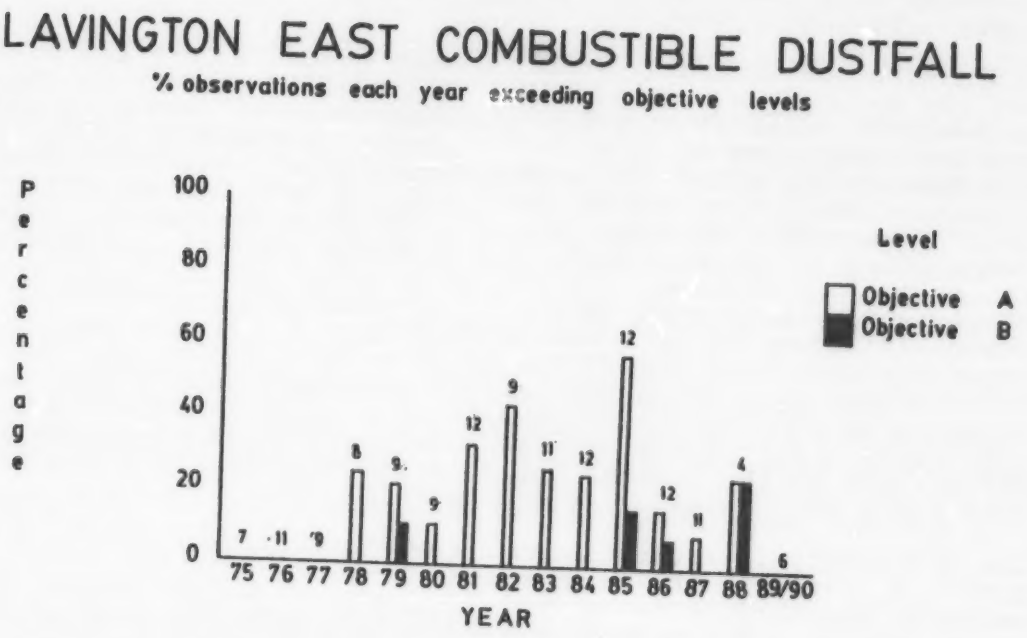
4.0 GENERAL DISCUSSION

Anecdotal stories of the dustfall problem in Lumby are common. These subjective views are corroborated by quantitative evidence from air quality monitoring programs carried out by both B.C.E. and the companies licensed to operate woodwaste burners. That parts of the Lumby - Lavington airshed are subject to dustfall deposition excess of provincially recommended levels is undeniable. The provincial air quality objectives define MAXIMUM dustfall rates to which humans should be subjected. Yet in many years the MEDIAN value for combustible dustfall alone approximates that maximum recommended level. As incontrovertible as the problem is, so the sources and the remedies are subject to controversy.

4.1 The Source of the Problem

The dust source can be best approached with two questions; 1) is it the lumber mills? and 2) is it their woodwaste burners?

Figure 20. Percentage of combustible dustfall observations each year at the Lavington East exceeding B.C. air quality objective level A (<1.75 mg/dm²/day) or objective level B (>2.9 mg/dm²/day).



Possible alternatives to the lumber mills as sources of dustfall in Lumby - Lavington are home heating with wood stoves, pollen, air-borne soil particles stirred up by wind and agricultural activity, and air-borne dust from gravel roads and work areas. The first two can be dismissed because even with seasonal fluctuations there is still a significant dustfall problem during periods of the year when neither fires nor pollen could be implicated. It is also doubtful if pollen reaches the air-borne concentrations needed to produce the observed dustfall. The second two can be eliminated by showing that a problem still exists when the non-combustible fraction of the dustfall is factored out.

Evidence that the mills are major factors in generating dust comes from four observations:

i) There is a relationship between yearly median rates of dustfall and distance from the nearest burner.

ii) There was a detectable decrease in dustfall rate when mill activities were stopped by a strike, but decrease at mills not affected by the strike.

iii) There was a detectable decrease in the combustible dustfall around the Fletcher Challenge mill while it was non-operational because of fire damage.

iv) There is a relationship between mill productivity and combustible dustfall for the Fletcher Challenge mill.

While monitoring burner emissions and the terms of permits have aimed at minimizing the generation of combustible dust by mills, the data clearly shows mills are still responsible for producing much of the non-combustible dustfall in this area. Consequently, there is little doubt that the activity of the mills should be targeted in attempting to improve air quality in the Lumby - Lavington area.

Concerning the second question, direct evidence that the burners are the major pollutant is weak. Affirmation comes from the decrease in dustfall at Lumby when the Fletcher Challenge burner had been destroyed by fire, and from the decrease in combustible dustfall at Lavington with installation of the new refractory burner. Temperature recordings from 1986 and 1987 show the normal operating temperature at around 1000° Fahrenheit. This temperature is routinely reached within an hour of firing up.

Conversely, attempts to establish a relationship between combustible dustfall and burner operating efficiency were unsuccessful. This should not be taken as evidence that such a relationship does not exist. Indeed, conventional wisdom based on man's ancient relationship with fire, and the logic that opacity is a direct measure (at least with black smoke) of particulate matter between the observer and the light source, both imply such a casual relationship.

The difficulty in establishing a temperature/dustfall correlation must lie partly in the large margin of error inherent in the methods, the difficulty of quantifying data in the form of a strip record, and the burner operator's obvious lack of interest in maintaining complete and accurate records (at three of the mills the recording device was broken down for over three years or more).

Another obvious reason for the difficulty in establishing a relationship between combustible dustfall and burner activity is the contribution of other dust sources to settlement into the canisters. The extent to which cyclone and chip loader operation log yard work, or discharges from blow pipes onto saw-dust piles are independent of burner operation is unknown, but all could obscure the basic relationship between burning waste and creating dust. Several sites in the Okanagan subject to extremely high combustible dustfall are not associated with a burner, but are known to have problems with storing and transporting wood chip and sawdust (Richardson, Jensen and Bryan 1991).

Open burning, which is carried out by some mills under the conditions of their permit, probably contributes significantly but transiently to dustfall. Open burning is usually done annually, with fires burning for less than one week. The dustfall in that period may be high but the computation of yearly medians rather than means limits the effects of these isolated anomalies on data analysis. Slash burning has also been implicated in air pollution but contributes mainly to suspended particulates (Reid 1988), with the larger particles collected by dustfall canisters generally settling out close to the burn, and remote from habitation centres.

4.2 Solutions

Any attempt to address the problem of high and non-decreasing dustfall in the Lumby - Lavington area must be done with clear definitions of two central issues.

4.2.1 Acceptable and achievable levels of pollution.

People living in the area, mill operators, and B.C.E. are each likely to have different views on what are either achievable or acceptable. But if any clean-up program is to be effective, there must be agreement between these groups on this matter. Whatever the agreed levels, which will presumably be some compromise between the economic realities of keeping the mills running and the inhabitants long term health expectations, they must be seen by the mill operators to be achievable and they must be enforced by B.C.E.

In the event that it seems impossible to reach acceptable pollution levels with current methods, a variety of alternative strategies should be explored. Alternatives could include stock piling waste until there is sufficient for burners to operate efficiently, or for mills to combine their waste and operate burners as shared resources.

4.2.2 Measuring performance relative to objectives.

There must be a process of unambiguously indicating the level and source of any agreed pollutant. Monitoring programs are very costly and should be examined critically to determine if they are valid.

It is essential to continue tracking TSP levels as these probably constitute the greatest health threat. Also, since many people are concerned about visual pollution, burner temperature should be measured. Several mills have performed temperature - opacity correlations and show that there are critical operating temperatures in terms of smoke generation. Some satisfactory method of recording, quantifying, and storing this data needs to be established. The current temperature strip charts offer an easy recording method but create problems in interpretation and storage. The value of burner temperature as an index of dust emission is doubtful but should be explored further.

Recording dustfall data presents the greatest problem. Single dustfall canisters in Lumby and Lavington could adequately track relative changes in dustfall but would not address the problem of the source of the dust. It seems incumbent on the mills to establish that their mill is not contributing excessively to the problem. The only sure way of doing this would be to show that dustfall was a decreasing function of distance from their centre of operation, reaching acceptable limits at their boundary.

5. REFERENCES

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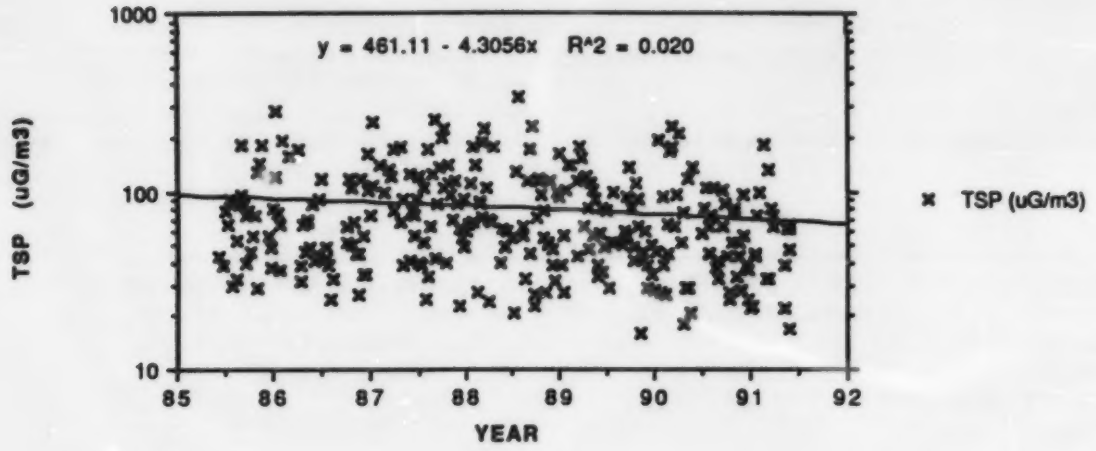
6. APPENDIX

Government air quality objectives

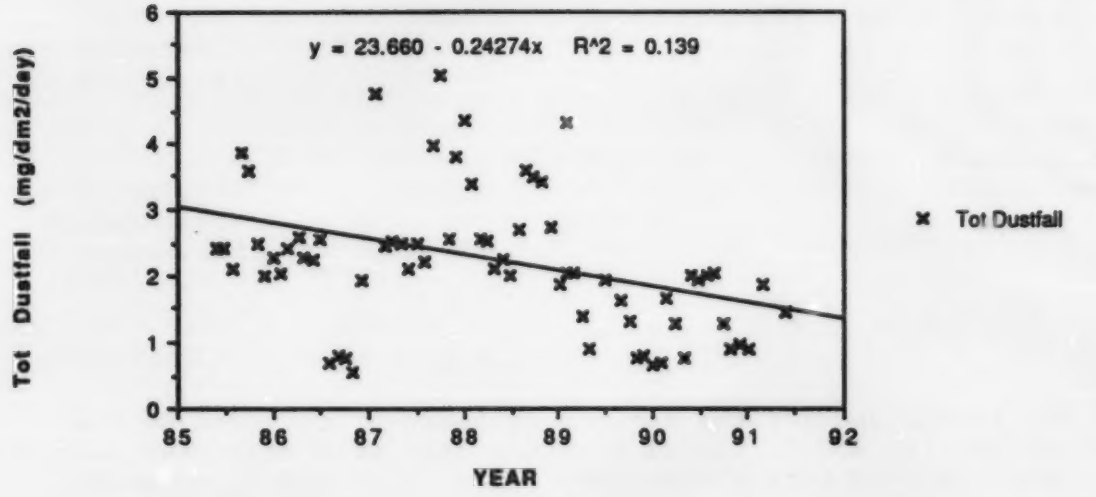
Parameter	Analysis period	Range	Objective level
Total acceptable suspended tolerable particulates (ug/m^3)	24 hours	<120	Federal
		120-400	Federal
		<150	Provincial A
		150-200	Provincial B
		>200	Provincial C
desirable	year (geometric mean)	<60	Federal & Provincial A
		60-70	Provincial B
		70-75	Provincial C
Total dustfall ($mg/dm^2/d$)	1 month	<1.75	Provincial A (residential)
		<2.90	Provincial B

* All levels specify the maximum contaminant for each of the three Levels: A,B,C. Level A is the desirable objective intended to provide long term protection. Level B is the acceptable objective which will provide adequate protection from adverse effects on health of plants, animals, and humans. Level C is the tolerable objective which denotes the level of air contaminant that requires appropriate action to prevent exceedances, because greater levels imply a diminishing margin of safety for health of plants, animals, or humans.

Appendix Figure 1. TSP @ Lumby HomeFurn.



Appendix Figure 2. Dustfall @ Lumby HomeF.



Appendix Figure 3. Lumby Combust Dustfall